



# 2009 Minerals Yearbook

## KYANITE AND RELATED MATERIALS

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The United States continued to be the world's leading producer of kyanite and mullite (calcined kyanite), with production of 71,000 metric tons (t) in 2009 (table 3). Production of synthetic mullite in the United States was an estimated 40,000 t. Andalusite was mined and marketed as part of a mineral mixture at one U.S. operation, but data were withheld to avoid disclosing company proprietary data. There was no reported U.S. production of sillimanite. Refractory products continued to be a major end use for kyanite and related materials.

This report includes information on andalusite, kyanite, and sillimanite (all of which have the formula  $Al_2SiO_5$ ), and mullite and synthetic mullite ( $3Al_2O_3 \cdot 2SiO_2$ ). Mullite, a refractory (heat-resistant) material, can be made by calcining kyanite at high temperature (for example, above 1,450 °C). By contrast, synthetic mullite refers to mullite made by calcining at high temperature certain mixtures of alumina- and silica-containing minerals and materials, including bauxite and kaolin.

## Production

Kyanite Mining Corp. (KMC), the sole U.S. producer of kyanite and kyanite-derived mullite, operated two open pit mines in Buckingham County, VA, and beneficiated the ore into a marketable kyanite concentrate. The company also had two kilns at its Dillwyn, VA, facility for the production of mullite from kyanite. Reported U.S. production data collected by the U.S. Geological Survey (USGS) were withheld to avoid disclosing company proprietary data. Production was estimated through employment data provided by the Mine Safety and Health Administration (MSHA) and nongovernment estimates from previous years. In 2009, 71,000 t of kyanite was reported produced in the United States, a decrease of about 27% compared with the reported production of 97,200 t in 2008 (Lassetter, 2009, 2010). The estimated value of the kyanite produced in the United States in 2009 was \$20 million, a decrease of 21% compared with \$26 million in 2008. The average unit value for raw and worked kyanite increased by 8% compared with the average unit price for 2008. KMC's mullite product contained about 80% mullite (Kyanite Mining Corp., 2006). Synthetic mullite, made from calcined bauxitic kaolin and sold by C-E Minerals, Inc., contained up to 87% mullite and was produced near Americus, GA (C-E Minerals, 2010). Based on nongovernment estimates from previous years, estimated U.S. production of synthetic mullite was about 40,000 t in 2009; the estimated value for the material was about \$10 million.

Piedmont Minerals Co., Inc. in Hillsborough, NC, mined a deposit containing andalusite combined with pyrophyllite and sericite. The company sold products containing blends of the three minerals to producers of ceramics and refractories.

## Consumption

Kyanite increases in volume by 16% to 18% when calcined to mullite and can be used in its raw concentrate form in a

refractory mixture to offset the shrinkage on firing of other components, especially clays. Andalusite expands irreversibly by about 4% to 6% when calcined, and can be used directly in refractories in its raw state (Dickson, 2006; Lassetter, 2007). In other refractory applications, kyanite concentrate is calcined to mullite before being added to refractory mixes if the volume increase of the kyanite is not required in the mix. Mullite is resistant to abrasion and penetration of deleterious dusts, gases, and slags. It also has beneficial creep resistance, which limits physical deformation under load at high temperatures (Roskill Information Services Ltd., 1990, p. 56, 63).

Examples of refractories that contain andalusite, kyanite, or mullite include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure), including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes.

Monolithic refractories are supplied in unfired and unshaped form, in contrast to prefired and preshaped brick products. They may be gunned, hand packed, moulded, poured, pumped, rammed, or vibrated into place (Moore, 2004).

Iron and steel production continued to be the leading user of refractories. World and U.S. crude steel output decreased for the second consecutive year, by about 8% and 36%, respectively, in 2009 from that of 2008. The leading steel-producing countries and their share of 2009 steel output of 1.22 billion metric tons were China, 47%; Japan, 7%; Russia, 5%; the United States, 5%; India, 5%; and the Republic of Korea, 4%. These countries accounted for 879 million metric tons of steel production in 2009, a slight decrease in production from the same countries compared with that of 2008 (World Steel Association, 2010a). Other refractories users were in the nonferrous metal and glass industries (Sweet, Dixon, and Snoddy, 2006). Other end uses of kyanite and related materials include brake shoes and pads, electrical porcelain, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2006).

## Foreign Trade

An estimated one-third of U.S. kyanite and mullite output was exported. Most of the material imported into the United States in 2009 was from France and South Africa and was presumed to be andalusite (table 2). In 2009, imports of andalusite decreased by 12% compared with those of 2008. No U.S. imports of kyanite or sillimanite were reported in 2009.

## World Review

South Africa continued to be the leading producing country of andalusite, with an estimated 210,000 t produced in 2009 (table 3). France produced an estimated 65,000 t of andalusite. Although China appeared to be a producer of kyanite and related minerals (Dickson, 2006), detailed production data have been unavailable since 2003 (O'Driscoll, 2010). India was the dominant producer of sillimanite, with an estimated

16,500 t of sillimanite and 7,700 t of kyanite in 2009. Countries that are thought to be producers of synthetic mullite [sintered mullite and (or) fused mullite] include Brazil, China, Germany, Hungary, and Japan (Taylor, 2005).

For refractories markets in China, India, and Japan, the steel industry used 70% to 75% of the tonnage. Two of the world's largest refractories companies reported that the steel industry accounted for about 60% of their annual sales worldwide (Semler, 2007a).

## Outlook

Natural raw materials, such as andalusite and kyanite, continue to be important in refractory manufacturing. For even more durable refractories, technology advances included increased usage of such processed raw materials as synthetic mullite. As the technology for manufacturing refractories continues to improve, the use of synthetic raw materials in the production of refractories could continue to grow. Other general material use trends could include the increased development and use of monolithic products and a gradual increase in the use of recycled refractory materials (Semler, 2007b).

China and Japan have been major locations for the production and consumption of refractories. Opportunities for market expansion could exist in other areas, such as the Commonwealth of Independent States, Eastern Europe, the Middle East, and Southeast Asia (Semler, 2007b).

For Canada, Mexico, and the United States, steel consumption was projected to increase in 2010 because of stock rebuilding coupled with a recovery in the U.S. economy. China's apparent steel use was projected to increase by 7% in 2010, and India may experience a 14% increase. World steel consumption was forecast to increase by 5% in 2010 compared with that of 2009 (World Steel Association, 2010b).

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## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

- Kyanite and Related Minerals. Ch. in Mineral Commodity Summaries, annual.
- Kyanite and Related Minerals. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

### Other

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TABLE 1  
PRICE OF KYANITE AND RELATED MATERIALS IN 2009

(Dollars per metric ton)

	Price
Kyanite, USA, ex-works, raw, 54% to 60% alumina	233–332
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 22-ton lots	387–456

Source: Industrial Minerals, December 2009, p. 69.

TABLE 2  
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE,  
KYANITE, AND SILLIMANITE<sup>1,2,3</sup>

Year	Quantity (metric tons)	Value <sup>4</sup> (thousands)
2008	5,580	\$1,930
2009	4,880	2,060

<sup>1</sup>Most material is andalusite from South Africa. No kyanite or sillimanite imports were reported.

<sup>2</sup>Harmonized Tariff Schedule of the United States code 2508.50.0000.

<sup>3</sup>Data are rounded to no more than three significant digits.

<sup>4</sup>Customs value.

Source: U.S. Census Bureau.

TABLE 3  
 KYANITE AND RELATED MATERIALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY<sup>1,2</sup>

(Metric tons)

Country and commodity <sup>3</sup>	2005	2006	2007	2008	2009
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite <sup>4</sup>	300	300	300	300	300
Brazil, kyanite, marketable	600	600	600	600	600
China, unspecified	3,400	3,400	3,500	4,000	4,000
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	6,800	7,000	7,300	7,500	7,700
Sillimanite	15,000	15,000	15,200	16,000	16,500
South Africa, andalusite	228,265 <sup>5</sup>	221,209 <sup>5</sup>	264,645 <sup>5</sup>	216,667 <sup>r,5</sup>	210,000
United States:					
Kyanite	100,000 <sup>r,6</sup>	100,000 <sup>r,6</sup>	118,000 <sup>7</sup>	97,200 <sup>r,8</sup>	71,000 <sup>9</sup>
Mullite, synthetic	40,000	40,000	40,000	40,000	40,000

<sup>r</sup>Revised.

<sup>1</sup>U.S. and estimated data are rounded to no more than three significant digits.

<sup>2</sup>Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 26, 2010.

<sup>3</sup>In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

<sup>4</sup>In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) that contains 40% to 48% Al<sub>2</sub>O<sub>3</sub> is produced.

<sup>5</sup>Reported figure.

<sup>6</sup>Estimated based on the part 50 report published by the Mine Safety and Health Administration. (Accessed March 9, 2009, via <http://www.msha.gov/stats/part50/p50y2k/aetable.htm>).

<sup>7</sup>Source: Lassetter, W.L., Jr., 2008, Kyanite, andalusite, sillimanite and mullite: *Mining Engineering*, v. 60, no. 6, June, p. 44–45.

<sup>8</sup>Source: Lassetter, W.L., Jr., 2009, Sillimanite minerals: *Mining Engineering*, v. 61, no. 6, June, p. 68–69.

<sup>9</sup>Source: Lassetter, W.L., Jr., 2010, Sillimanite minerals: *Mining Engineering*, v. 62, no. 6, June, p. 74–76.